# Fiber Qualities and Culture of Phormium in California

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# Fiber Qualities and Culture of Phormium in California[1]

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Phormium (*Phormium tenax* Forst.), a perennial herb native to New Zealand and Norfolk Island, is grown in many countries as an ornamental and as a source of fiber for cordage. It has become widely established as a garden and park plant in California, both along the coast and on inland areas. Although at present its importance in California is due chiefly to its decorative nature, it was introduced (in 1858) and first propagated in the State mainly because of the value of its fiber. The earliest publications referring to phormium as a California plant (*8*, *12*, *15*, *16*, *25*)[2] mention it as furnishing convenient tying material for use in gardens and vineyards.

The phormium plant has a compound rhizome and produces long upright sword-shaped leaves in fans, or shoots, that form clumps (fig. 1). The mature plant, grown under the most favorable California conditions, has leaves about 8 to 12 feet long.

Nineteenth-century reports of the U.S. Department of Agriculture and the University of California (*8*, *12*, *15*) include numerous accounts of phormium culture in California. In general they indicate that phormium, if it once gets started, will grow in almost any part of the State where frosts are not too heavy, but that in the interior valleys and along the coast south of San Luis Obispo it needs irrigation and partial shade.

Between 1917 and 1920, interest in fiber production led the U.S. Department of Agriculture to make experimental plantings of phormium along the west coast from San Diego, Calif., to Seattle, Wash., and as far inland as Brawley, Fresno, and Chico, Calif. The studies reported in this publication were made in 1950–60. Thousands of phormium plants were set out on 28 California areas ranging in size from a few square yards to an acre or more, along the coast from

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[1] The 1950–60 studies on which this report is chiefly based were made in cooperation with the University of California Botanic Garden and Department of Botany.

[2] Italic number in parentheses refer to Literature Cited, p. 19.

FIGURE 1.—Phormium in an unirrigated plot in Berkeley (above) when about 4 years old, in 1955, and (below) when about 9 years old.

San Luis Obispo to the State's northern boundary. Data on these plantings, together with records and observations on plants in gardens, afford ample evidence that there are large areas in California where environmental conditions favor phormium. In much of the area where the plant has ornamental value, however, its culture for fiber is limited by such factors as the relatively high land costs and the labor requirement.

## ENVIRONMENTAL AND CULTURAL REQUIREMENTS

### Temperature

Death of phormium in California due to cold weather has been reported (*12*) from only one locality—Cayton, Shasta County, about 3,300 feet above sea level. The lethal temperature was not determined. In other California areas, both inland and on the coast, temperatures of 24° to 18° F. have caused little or no damage to phormium.

In the bright, hot valleys of California, shaded plants usually grow large and vigorous, but exposed ones fail to grow to full size and frequently have sunburned leaves.

### Humidity and Irrigation

Phormium grows better on coastal areas of California than it does on the warmer, less humid inland areas. Plants on coastal areas north of Santa Cruz grew well under natural moisture conditions (fig. 1), but those on inland areas and on the coast south of Santa Cruz required light to moderate irrigation. Coastal plantings in the cool and foggy vicinity of Inverness yielded 1.4 times as many pounds of fresh leaves per acre per year as those in the slightly warmer, drier vicinity of Berkeley. The Inverness plants also flowered and fruited more freely. In a 2-year period they averaged 3.2 inflorescences per plant per year, while the Berkeley plants averaged only 1.5.

The most luxuriant phormium growth and reproduction observed were found in irrigated gardens and parks in or near San Francisco (fig. 2), Eureka, and Crescent City.

### Kind of Soil, Soil Tilth, and Drainage

Phormium grows well in many kinds of soil. It grows best in rich alluvial loam or peat. Plants in alluvial soil near Cambria, on an average, had about 1.2 times as many shoots and about 1.7 times as great leaf lengths as plants of the same age growing nearby in hillside gravel. At Berkeley, plants grown in fine loam yielded 1.5 times as great weights of fresh leaves as those in adobe.

All plantings made on weed-free, semicultivated soil rooted rapidly and grew vigorously. After 2 or 3 years, the plants were large enough to compete with weeds and become adjusted to natural soil conditions. The plants set out on weedy, packed soil rooted poorly and either died or barely survived. After 6 or more years in the field, those surviving were scarcely larger than when planted.

FIGURE 2.—Volunteer phormium seedlings around irrigated mature phormium plants in Golden Gate Park, San Francisco, 1950.

Phormium has been reported to grow best in moderately moist, well-drained soil (*8*). In plantings near Cambria, a gradual transition from good to poor growth accompanied that from well-drained to swampy soil; on a swampy area near Inverness, only the plants set out on small knolls survived; and at Trinidad well-drained, poorly drained, and semiswamp areas, respectively, produced fairly good, medium, and poor plants.

Fertilizer tests involving nitrogen, phosphate, and potash used singly and in all combinations were conducted on two sites. The fertilizers appeared to have no effect on leaf yield, fiber percentage, or fiber quality.

## INJURY BY RODENTS, CATTLE, AND INSECTS

Mice and pocket gophers caused serious damage to phormium plants. Mouse injury occurred chiefly in the San Francisco Bay vicinity. Gopher damage extended from Cambria northward. In severe infestations near Inverness, gophers destroyed more than 400 large plants within 2 years and mice badly damaged from 3.6 to 5.9 percent of the fresh leaves of 565 plants within a few months.

Cattle destroyed many seedlings and divisions. All plants destroyed by cattle were newly planted ones that the cattle simply pulled out of the ground. When cattle got among well-established plants, they neither ate nor mutilated them. No evidence was found that cattle ate phormium plants, although an 1887 report of the

University of California (*16*) quoted a letter saying that cattle had done so.

Red scale (*Chrysomphalus aurantii* Mask.), red spider (*Tetranychus telarius* (L.) and *Tetranychus* sp.), and mealybug (*Pseudococcus* spp.) were found to infest phormium. Red scale occurred only on the leaves of a few poorly kept garden plants in southern California. Red spiders attacked plants as far north as Berkeley; mealybugs, as far north as Fort Bragg. In the experimental field plantings, both these insects were comparatively scarce and rarely required control. In greenhouses, on the other hand, they became plentiful enough to cause considerable damage unless controlled. Red spider infested only the leaves of fairly young plants. Mealybug attacked leaves, stems, and roots of both young and old plants. Dense infestations of red spider caused the leaves to become mottled with a whitish color. Similar concentrations of mealybug caused them to turn yellow. In both cases the leaves and then the plant usually died prematurely.

## DISEASES

Three diseases were found to be serious in phormium: Damping-off (caused by *Pythium* sp.), charcoal rot (caused by *Sclerotium bataticola* Taub.), and anthracnose (caused by *Collitatrichum gleosporioides* Penz.). Damping-off infestations were limited to crowded seedlings in greenhouse flats.

The symptoms of charcoal rot are very similar to those reported (*3, 4*) for yellow-leaf disease. The affected stems rot, and the leaves turn yellow. Charcoal rot progresses slowly from one shoot of a plant to another. In a few instances its progress stopped and the remaining shoots continued to grow normally.

The occurrence of charcoal rot depended largely upon the culture and growing condition of the plants. It was less during the rainy season and in well-kept plantings. At Cambria and Eureka, plantings that had been free of the disease became badly infected when cultivation and irrigation were discontinued. In the vicinity of San Francisco Bay the disease did not occur in plantings near Inverness but was common in the somewhat warmer, drier locality of Berkeley (table 1).

Charcoal rot was more common in seedling populations than in clones, and the difference in percentage of infection among diseased clones was much greater than that among diseased seedling populations (table 1). The data suggest that some clones have complete resistance and some others have none, and that a seedling population may be entirely resistant or contain both resistant and susceptible individuals. The yearly decrease in seedling losses in a planting

TABLE 1.—*Incidence of charcoal rot in phormium clones and seedling populations, Berkeley, 1956*

| Type of plant | Populations | Plants | Age of plants | Diseased individuals | Diseased populations | Infection within diseased populations |
|---|---|---|---|---|---|---|
| | *Number* | *Number* | *Years* | *Percent* | *Percent* | *Percent* |
| Propagule | 59 | 893 | 2¾ to 3¾ | 6. 05 | 40. 68 | 0. 78 to 100. 00 |
| Seedling | 20 | 958 | 4½ to 5½ | 9. 29 | 46. 67 | 5. 26 to 19. 06 |

(512 plants) observed at Berkeley, from 1.58 percent at 3½ years to 1.17 percent at 4½ years and 0.78 percent at 5½ years, suggests that the percentage of susceptible plants was being reduced.

Anthracnose lesions appeared as small yellow areas on the expanded part of the leaf. These areas slowly enlarged, then the affected parts of the leaf died. Finally the dead parts turned straw color, and numerous black, dotlike abrasions developed on them.

The incidence of anthracnose varied according to the leaves' state of vigor. At Berkeley, the disease occurred mainly on leaves that had been sunburned. Not only was the disease more prevalent on drooping-leafed plants, but 88 percent of the infections on such plants were at or above the area where the droop began.

Anthracnose occurred in all plantings from Cambria northward. At Berkeley, in 1958, approximately 44 percent of the plants had anthracnose; but it was estimated that less than 1 percent of the leaves of these plants were diseased. Near Inverness, at the same time, only 26 percent of the plants were diseased, only one or two leaves of each diseased plant were affected, and the symptoms were mild.

## WEED CONTROL

Although the observation that young planted phormium cannot compete with weeds has been reported in several publications (*6, 13, 21, 23*), no information on chemical weed control in phormium culture was available when the present studies began. On the basis of results of considerable experimentation with a dozen or more chemical treatments, the following were used to control weeds in the experimental plantings:

Preemergence control of annual weeds: Diuron [3-(3,4 dichlorophenyl)-1,1-dimethylurea] applied at 6.0 pounds per acre shortly before or after the first winter rains, or applied at 4.0 pounds per acre at such a time and again at 2.0 pounds per acre in early spring before the last spring rains.

Postemergence control: (1) General: DNBP, the alkanolamine sale (Ethanol and Isopropanol series) of [4,6-dinitro-o-sec-butylphenol] at 3.0 pounds per acre. (2) Broadleaf weeds: 2,4-D at 2.0 pounds per acre. (3) Monocotyledons: dalapon [sodium salt of 2,2-dichloropropionic acid] at 5.0 pounds per acre, applied on a warm, sunny day.

Combinations: To control broadleaf weeds, perennial or annual, diuron at 2.0 and 4.0 pounds and 2,4-D at 2.0 pounds per acre were frequently combined. Occasionally combinations of diuron and dalapon or of diuron and DNBP were used.

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At the strengths given, none of the chemicals was observed to injure phormium. (C. R. Stanton has reported that dalapon slightly injured some phormium leaves in plantings near Yachats, Oreg.)

# YIELD

## Fresh Leaves

Investigators (*6*, *10*, *19*, *21*) have reported the ages at which phormium plants in New Zealand and elsewhere yield their first harvest of leaves as from 3 to 6 years for divisions and from 5 to 8 years for seedlings, and have reported yields of fresh leaves per acre per year as from 5 to 11 tons. In the California studies, yield was determined for eight plantings in which the plants were spaced 6 x 6 feet (table 2). Ages at first harvest corresponded with those previously reported for divisions but were 4 years or less for seedlings, and the range of yield per acre was from 1.2 to 9.3 tons. The seedling yields (at Berkeley), although they seem low, were increasing at a fairly rapid rate; the 4-year-old seedlings yielded about 400 pounds per acre per year more than those 5 months younger.

## Fiber Percentage and Related Leaf Characteristics

The fiber yield of fresh phormium leaves grown in New Zealand and elsewhere has been reported as ranging from 5.2 to 27.4 percent for unscutched fiber and from 2.5 to 18.8 percent for finished fiber (*3*, *19*, *23*). The variation can be attributed principally to these causes.

TABLE 2.—*Yield of fresh leaves of phormium plants spaced 6 x 6 feet in 8 plantings, Berkeley and Inverness, 1950–60*

| Locality and plants | Age of leaves at harvest | Yield per acre per year |
|---|---|---|
| | *Months* | *Tons* |
| Berkeley: | | |
| 68 seedlings | 43 | 1. 2 |
| 143 seedlings | 48 | 1. 4 |
| 5 plants of clone 4 | 56 | 6. 6 |
| 90 plants of clone 1 | 69 | 3. 5 |
| Inverness: | | |
| 138 plants of clone 34 | 53 | 6. 6 |
| 5 plants of clone 4 | 56 | 9. 3 |
| 12 plants of 2 clones | 35 | 2. 7 |
| 36 plants of 6 clones | 45 | 7. 6 |

(1) Differences in proportion of fiber among varieties.

(2) Lack of a uniform standard for determining and reporting proportion of fiber.

(3) Calculating fiber content on the basis of unclean fiber and of varying degrees of fiber recovery (*1, 3, 11, 18, 26*).

(4) Calculating fiber content on the basis of an inadequate quantity of material. Ample material is needed because of differences in fiber content among different parts of the leaf (*11*), among leaves of different ages (*9, 24*), and among leaves from different locations within the plant clump.

The average fiber yield of fresh leaves of phormium has been reported to range among different varieties from 5.2 to 22.4 percent for unscutched fiber and from 2.5 to 18.8 percent for finished fiber (*1, 11, 23*).

The moisture content of phormium leafage has been reported (*1, 5*) to average about 70.0 percent for the whole leaf, 62.6 percent for the top, and about 74.0 percent for the butt. (The terms "butt" and "top," as used here, designate the parts below and above the line at which the leaf unfolds.) The moisture content of leaves from outside fans of 15 clones at Berkeley ranged from 71.2 to 74.5 percent, averaging 72.9 percent (table 3). In another series of 16 clones moisture content

TABLE 3.—*Moisture content, butt-top weight ratio, and fiber yield of fresh phormium leaves from outside fans of 15 clones, Berkeley*

| Clone No. | Moisture content [1] | Butt-top weight ratio [1] | Fiber yield [2] |
|---|---|---|---|
| | *Percent* | | *Percent* |
| 1 | 73.10 | 2.60 | 18.72 |
| 2 | 73.29 | 3.43 | 18.05 |
| 3 | 71.63 | 2.14 | 19.12 |
| 4 | 71.39 | 2.03 | 19.94 |
| 5 | 74.47 | 2.60 | 17.97 |
| 6 | 72.85 | 2.45 | 17.46 |
| 7 | 72.32 | 2.24 | 18.95 |
| 8 | 73.37 | 2.82 | 20.38 |
| 9 | 74.26 | 3.36 | 16.36 |
| 10 | 73.58 | 2.67 | 18.67 |
| 11 | 73.74 | 2.85 | 18.07 |
| 12 | 71.16 | 1.73 | 19.85 |
| 13 | 72.89 | 2.95 | 18.98 |
| 14 | 72.11 | 2.16 | 17.20 |
| 15 | 73.32 | 2.70 | 19.55 |
| Average | 72.90 | 2.58 | 18.62 |

[1] Determinations based on longitudinal halves of the 1st, 2d, and 3d leaves of one half of each fan.

[2] Determinations based on fresh weights of the 1st and 3d leaves of the other half of each fan used in determining moisture content and butt-top weight ratio and the weight of mechanically processed air-dried fiber. (Tests indicated that the processed and air-dried fiber contained about 1.5 percent moisture.)

ranged from 71.5 to 75.2 percent for the whole leaf, from 61.2 to 66.3 percent for the leaf top, and from 73.8 to 80.3 percent for the leaf butt.

Among 30 clones at Berkeley the average fiber yield ranged from 16.5 to 20.6 percent for partly clean air-dried fiber. Among the 15 of these clones represented in table 3 the fiber yield of leaves from outside fans ranged from 16.36 to 20.38 percent on an air-dried basis and from 14.86 to 18.88 percent (average, 17.12 percent) on a moisture-free basis. According to these figures, the residue ranged from 8.75 to 12.19 percent and averaged 9.98 percent. The residue includes cuticle, gum, chlorophyll, etc.

Fiber percentage in the phormium leaf is correlated with the butt-top weight ratio (the weight of the butt divided by the weight of the top). For the 15 clones at Berkeley represented in table 3, this correlation is −0.6475. This shows that the butt-top weight ratio of these clones determined their fiber yield to the extent of 42 percent. Among these 15 clones the butt-top weight ratio ranged from 1.73 to 3.43, averaging 2.58. Because the butt-top weight ratio is not constant, combined averages of butt and top fiber percentages fail to reflect accurately the percentages of fiber in whole leaves.

In four clones at Berkeley for which butt-top ratio was considered with reference to leaf age and fan location (inside or outside), the ratio varied significantly with both factors (table 4). Its greatest difference according to age of leaf was between the youngest and the next-to-youngest pair of leaves. The average ratio for the second pair of leaves was 1.2 times that for the youngest. The average ratio for leaves from inside fans of the plant clump (3.03) likewise was 1.2 times that for leaves from outside fans (2.58).

Significant differences in average fiber yield were found between butts and tops and between bruised and unbruised leaf material (table 5). Bruised butts yielded more fiber than the unbruised, but bruised tops yielded less than the unbruised. Old butts yielded more than the young, but old tops yielded less than the young. Fiber percentage increased upward in the butt, reached a maximum in the lower part of the top, and decreased in the upper part of the top.

Fiber loss was greater in bruised than in unbruised material, less in young leaves than in old leaves, and much less in butts (0.34 percent) than in tops (1.93 percent).

TABLE 4.—*Butt-top weight ratio of fresh phormium leaves by leaf age and location of fan, Berkeley* [1]

| Pair of leaves | Clone No. 16 | | Clone No. 17 | | Clone No. 18 | | Clone No. 19 | | Average |
|---|---|---|---|---|---|---|---|---|---|
| | Outside fan | Inside fan | Outside fan | Inside fan | Outside fan | Inside fan | Outside fan | Inside fan | |
| First | 2. 13 | 2. 91 | 3. 98 | 4. 29 | 1. 67 | 2. 12 | 1. 34 | 1. 89 | 2. 54 c |
| Second | 2. 94 | 3. 81 | 4. 65 | 5. 02 | 1. 90 | 2. 27 | 1. 80 | 2. 09 | 3. 06 a |
| Third | 2. 50 | 3. 09 | 4. 50 | 4. 78 | 1. 78 | 2. 12 | 1. 78 | 1. 96 | 2. 81 b |
| Average | 2. 52 d | 3. 29 c | 4. 37 b | 4. 70 a | 1. 78 f | 2. 17 e | 1. 64 f | 1. 98 ef | |
| Average for outisde and inside fans | | 2. 90 b | | 4. 53 a | | 1. 98 c | | 1. 81 c | 2. 80 |

[1] Leaves were cut 5 inches above leaf base. Any two means within the same cell (space enclosed by heavy lines) that are not followed by the same letter differ significantly from each other at the 5-percent level.

TABLE 5.—*Average total fiber yield, and average fiber loss (tow) in hand stripping, of phormium leaf material according to location in the leaf, age of leaf, and condition as to bruising, Berkeley* [1]

| Leaf material | Butt | Top | Average for butt and top combined | Average fiber loss (tow) |
|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* |
| Unbruised | 9. 93 a | 19. 31 d | 14. 62 b | 0. 95 |
| Bruised | 10. 88 b | 16. 57 c | 13. 72 a | 1. 31 |
| Old | 10. 85 b | 17. 07 c | 13. 96 a | 1. 26 |
| Young | 9. 96 a | 18. 82 d | 14. 39 a | 1. 00 |
| Lower part | 9. 05 a | 18. 75 d | 13. 90 a | 1. 11 |
| Upper part | 11. 76 b | 17. 14 c | 14. 45 a | 1. 16 |
| Average | 10. 41 a | 17. 94 b | | |

[1] The terms "butt" and "top," as used here, designate the parts below and above the line at which the leaf unfolds. "Young" leaf material=first pair of leaves, on opposite sides of center juvenile leaf. "Old" leaf material=third pair of leaves. Bruising was done deliberately to facilitate processing. It did not simulate standard utilization procedure. Material represented by data: 7½-inch sections from a single plant of each of 2 clones, as follows: Lower and upper parts of butt and of top, 24 sections each; butt and top, 48 sections each; old, young, bruised, and unbruised, 96 sections each. Process: 15-lb. steam pressure for 3 hours in 8 cc. of 3.0-percent aqueous solution of sodium sulfite per gram of fresh leaves. Percentages are based on weights of fresh material and of moisture-free fiber. Any two means within the same cell (space enclosed by heavy lines) that are not followed by the same letter differ significantly from each other at the 5-percent level.

## FIBER QUALITY

The color of phormium fiber has been reported as nearly white, brownish yellow, and reddish yellow, and its length as from 3 to 12 feet (*7*, *17*, *19*, *26*). There is considerable disagreement as to the strength and weathering qualities of the fiber (*2*, *7*, *14*, *19*, *26*, *27*). In general, phormium fiber is considered to be weaker and less resistant to moisture than abaca, about equal in both qualities to sisal, and stronger and more resistant to weathering than henequen. Test ropes made by the Materials Laboratory, Boston Naval Shipyard, from phormium fiber produced in Oregon were reported (*22*) to have fair physical properties but to be deficient in weather resistance, particularly in marine environments. Ropes blended of half phormium and half Central American abaca in general had 85 percent as much strength and durability as ropes made entirely of Central American abaca, and they compared favorably with sisal ropes.

# PROPAGATION

## Seed

Fresh seed of phormium has been reported to germinate within 3 to 10 weeks after planting and to be about 30 to 75 percent viable (*13, 20, 24*). In the 1950–60 study, cooperative tests conducted by E. H. Toole, of the Agricultural Research Service, resulted as follows:

(1) In tests involving constant and alternating temperatures ranging from 50° to 95° F., the greatest germination occurred at alternating temperatures of 59° for 16 hours and 77° for 8 hours.

(2) Viability of seed stored at uncontrolled temperatures and humidity at Berkeley fell significantly after 10 months of storage.

(3) Viability of seed stored 1 to 2 years at 50° F. and 50-percent relative humidity at Beltsville did not fall.

(4) Fresh seeds were dormant for an undetermined length of time. This dormancy was shown by the fact that germination increased during the first few months of storage.

(5) The maximum viability of six samples of seed ranged from 30 to 92 percent and averaged 65 percent.

(6) Although germination proceeded very slowly, practically all of it took place within 60 days.

At Riverside and Berkeley the time required for germination in flats and seedbeds ranged from 3 to 16 weeks. The heaviest germination occurred within 6 weeks. Sporadic germination continued for 5 or more months. Germination of one lot of mixed seed extended the 6th week through the 26th month, the bulk of it occurring within about 8 weeks. At Inverness, seed planted in May and August on irrigated field plots germinated within 8 weeks, but seed planted at the same times on unirrigated plots did not germinate until the following spring.

Volunteer seedlings are common around irrigated plants in Golden Gate Park, San Francisco (fig. 3).

Under favorable conditions, seedlings grow large enough for planting in permanent positions within a year. They mature sufficiently for harvest within 5 to 8 years. However, seed cannot be relied upon to produce uniformly good plants and therefore should not be used for crop production.

## Propagules

Phormium propagules may be either divisions or cuttings. Divisions are shoots or fans that have been separated from a mother plant. One division may consist of a single fan or a group of two or more fans. Divisions are planted in permanent positions. Experiments conducted at Berkeley and Inverness showed that both the size of the division and its growing condition at planting time have an important effect on plant establishment. At Berkeley about 19 percent of 144 single-fan divisions died within a year after planting. Of those lost, 73 percent had not more than three pairs of leaves; 80 percent were planted during the dry months of April, June, and August; and 93 percent were not irrigated.

Table 6 gives the yield at 35 and at 45 months of plants that developed from divisions planted in hills of six types at Inverness. The data afford a basis for the following statements:

(1) Yield varied directly with the number of fans included in the hill.

(2) In the series harvested twice, 40 percent of the total yield was produced in the 10 months following the first cutting. (Comparable second growth of phormium is illustrated in fig. 3.)

(3) Yield per fan varied inversely with number of fans per division.

(4) This trend of yield per fan, in conjunction with the relative yields of the single-fan and multiple-fan hills at 35 months and at

FIGURE 3.—New growth of phormium, 9 months old, from roots of a plant harvested at the age of 5¾ years in the University of California's Berkeley Field, 1960. The new leaves are more than three-fourths as long as those harvested and weigh 35.78 percent as much.

TABLE 6.—*Fresh-leaf yield of phormium divisions planted in hills of 6 types, Inverness*

| Type of hill, in terms of fan or fans [1] | Average yield of 2 replications [2] harvested twice | | | Average yield of 6 replications [2] harvested once, at 45 months |
|---|---|---|---|---|
| | At 35 months | At 45 months | Total in 45 months | |
| | *Grams* | *Grams* | *Grams* | *Grams* |
| Single fan: | | | | |
| Large | 5, 130 | 5, 400 | 10, 530 | 17, 833 |
| Small | 7, 050 | 5, 800 | 12, 850 | 9, 733 |
| Two or three fans: | | | | |
| United: | | | | |
| Two large | 8, 810 | 7, 100 | 15, 910 | 21, 300 |
| Three large | 11, 970 | 8, 000 | 19, 970 | 27, 467 |
| Separated: | | | | |
| Two large | 10, 560 | 5, 900 | 16, 460 | 22, 467 |
| Three large | 12, 170 | 6, 500 | 18, 670 | 26, 167 |
| Average | 9, 282 | 6, 450 | 15, 732 | 20, 821 |

[1] Large fans had 5 pairs of leaves each; small fans had 3 pairs of leaves each.
[2] Each replication was a single clone and included 1 hill of each type. Spacing was such that plant growth was not seriously affected by competition.

45 months, indicates that the three types of plantings were approaching equality in yield.

Several minor objections to propagating phormium by division have been cited (*3*, *13*, *24*). The main disadvantage is the limited number of new plants procurable from a plant. This can be avoided by using cuttings.

Stem cuttings rooted and sprouted freely even when planted at random in exposed sand beds. They required no special treatment. The growth of various types of stem cuttings is shown in table 7.

The results in table 7, and other data on the material represented by the table, show that success in obtaining plants from stem cuttings varies according to the following:

(1) The age of the stem. About 93 percent of the plants obtained were from young-stem cuttings, although about 33 percent of the cuttings were from old stems.

(2) The part of the stem from which the cuttings are made. Cuttings from the apical region began growing several weeks earlier than those from the basal region (fig. 4). Furthermore, growth from old-stem cuttings clearly showed that the stems were differentiated into three zones: A nonrooting and nonsprouting base; a rooting midsection; and a rooting and sprouting apex.

(3) The density of the cutting's mother plant. Cuttings from equally old dense and less dense plants, respectively, averaged 3.6 and 2.8 sprouts per stem.

TABLE 7.—*Root and sprout formation in cuttings of various types from stems aged approximately 3 and 20 years, Berkeley*

| Approximate age of stem, and type of cutting [1] | Stems | Cuttings | Time [2] until— | | Plants obtained [3] |
|---|---|---|---|---|---|
| | | | Rooting | Sprouting | |
| 3 years: | *Number* | *Number* | *Weeks* | *Weeks* | *Number* |
| X | 15 | [4] 69 | 5–10 | 1–8 | 71 |
| ½ L | 17 | 34 | 1–7 | 3–10 | 34 |
| ¼ L | 8 | 32 | 1–12 | 3–7 | 21 |
| 20 years: | | | | | |
| X | 1 | 3 | 3–5 | 4 | 1 |
| ½ X | | 8 | 2–15 | 7 | 2 |
| ¼ X | | 12 | 2–6 | <1 | 0 |
| ⅛ X | | 24 | 4–16 | 5–7 | 1 |
| L | 1 | 2 | 3 | <1 | 0 |
| ½ L | | 4 | 2–3 | 4 | 1 |
| ¼ L | | 12 | 2–15 | 4–6 | 4 |

[1] X=cross section about 4 cm. thick. L=longitudinal section: an entire 3-year-old stem or an 8-cm. section of a 20-year-old stem. Cuttings were left unsplit or split into halves ("½"), quarters ("¼"), or eighths ("⅛").
[2] Counted from the time when the cuttings were made.
[3] All 32 of the ¼ L cuttings from young stems rooted. Out of a total of 65 old-stem cuttings, 34 rooted. In 2 cases an extra plant was obtained by splitting a cross section of a young stem between sprouts formed on opposite sides of the section. Each of 3 young-stem ½ L cuttings formed 2 sprouts.
[4] Data on 15 cross sections of succulent tips are excluded from the table because all sections of such tips decayed.

That cutting the stem into relatively small parts increases the number of sprouts is shown by the following:

(1) Young stems cut into longitudinal halves, quarters, and cross sections, respectively, averaged 2.2, 2.6, and 4.9 sprouts per stem.

(2) Eight of the nine old-stem cuttings that sprouted were split sections.

Plants from stem cuttings grow much faster than seedlings. Seven months after the cuttings were made, each of the resulting plants had one to three sprouts (on an average, two), the sprouts had two to seven leaves each (on an average, four), and the leaf length was 14 to 52 cm. (on an average, 25 cm.). Nine months after seedlings were planted, each seedling had one sprout and three to six leaves (on an average, four), and its leaf length was 12 to 41 cm. (on an average, 14 cm.). Every plant that originated from a cutting had principal roots abundantly supplied with secondary roots and rootlets. Prevailingly, however, each seedling still depended upon one rather poorly branched primary root.

## Time of Planting

In California's summer-dry climate, phormium should be planted in time to receive the full benefit of the winter's rain. Plants set

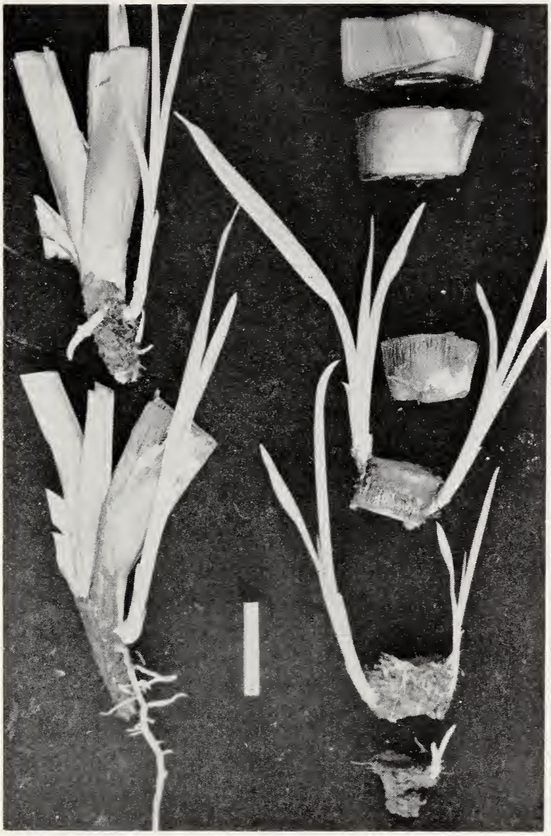

FIGURE 4.—Young-stem and leaf cuttings of phormium after 38 days of culture: Left, long cuttings; right, short cuttings. The top three short cuttings are composed of leaves; the next two are apical; the sixth, basal. Typically, basal parts of the stem are less productive than apical parts. At this stage productive short cuttings may be split in half to make two propagules each.

out in the field just before, or immediately after, the first rain in November are more likely to survive and grow well than those set out in the middle of the dry season.

## SUMMARY AND CONCLUSION

Phormium (*Phormium tenax* Forst.), a perennial herb native to New Zealand and Norfolk Island, is widely grown as an ornamental and as a source of fiber for cordage. All-phormium ropes have fair physical properties but in general are considered to be deficient in weather resistance. Test ropes blended of half-phormium and half-abaca had about 85 percent of the strength and durability of all-abaca ropes and compared favorably with sisal ropes. Phormium was introduced into California in 1858 and has become widely established as a garden and park plant along the coast and also on inland areas of the State. It thrives without irrigation along the foggy coast of northern California. In the warmer and drier parts of its present California range, the plant needs irrigation. Studies of phormium as a fiber crop for California, based on experimental plantings, were made in 1950–60.

Phormium grows well in many kinds of soil. It grows best in rich alluvial loam or peat. Tests with commercial fertilizers yielded no evidence of fertilizer effects.

Propagation is simple. The recommended method is field planting of divisions or cuttings. Seed cannot be relied upon to produce uniformly good plants. Cultural needs are mainly limited to control of weeds and rodents. Insects required control in some instances, principally in greenhouses. Red spider infested the leaves of fairly young plants; mealybug attacked leaves, stems, and roots of both young and old plants. Plantings in need of irrigation or cultivation were somewhat subject to charcoal rot and anthracnose.

Yield of fresh leaves per acre per year of planting spaced 6 x 6 feet, determined at Berkeley and Inverness, ranged from 1.2 to 9.4 tons. It was higher for clones than for seedlings.

Among 30 clones at Berkeley, fiber yield ranged from 16.5 to 20.6 percent for partly clean air-dried fiber. Among 15 of these clones, fiber yield of leaves from outside fans ranged from 16.36 to 20.38 percent, averaging 18.62 percent, on an air-dried basis and ranged from 14.86 to 18.88 percent, averaging 17.12 percent, on a moisture-free basis. The moisture content of fresh leaves from outside fans of these 15 clones ranged from 71.2 to 74.5 percent, averaging 72.9 percent. Fiber yield was correlated with the weight ratio of leaf butt and leaf top to the extent of −0.6475. Significant yield differences were found between butts and tops and between bruised and unbruised material. Fiber percentage increased upward in the butt, reached a maximum in the lower part of the top, and decreased in the upper part of the top.

The fiber has been described as nearly white, brownish yellow, or reddish yellow, and as 3 to 12 feet long.

The yields of fresh leaves, fiber yields, quality of fiber, and harvest periods for California correspond to those reported for regions in foreign countries where phormium fiber is produced commercially. However, commercial production of the fiber in California does not appear to be economically feasible. In parts of the State where the plant thrives, high cost of land would prohibit phormium culture or at least limit it to areas so inaccessible that costs of transporting the raw material to the mill would be a major expense. In the poorer growing areas extra cultural costs, lower yields, or the combination would prevent profit under present conditions. Harvesting and milling are expensive; both involve considerable hand labor. Furthermore, it appears doubtful that the production costs could be substantially reduced through cultural or technological improvements.

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